	Experiment title: Fatigue damage characterisation of particle reinforced metal-matrix composites by phase contrast microtomography	**Experiment number**: ME-288
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Report:

Advanced materials like particle reinforced metal–matrix composites (PMMC) have already many industrial applications, however the mechanisms governing their deformation and damage behaviour are not completely understood. Especially damage accumulation during fatigue presents one of the main problems, which needs to be clarified. The aim of the present work is to quantify quantitatively the damage in a fatigued Al6061 aluminium alloy reinforced with 20vol% alumina particles by the method of phasecontrast microtomography.

In order to see both, the bulk and the surface of investigated material the microtomographic method requires samples, which are small compared to the dimensions given in usual standards. The lower limit in our case was imposed by the accuracy of producing the samples in our workshop and their good handling in the testing machine. The value of 1.9 mm was chosen for the samples' diameter, which allowed the use of the 1.9 μm resolution in the tomographic measurements. In some cases the samples diameter has shown a variation of about 5-8% along the gauge-length, which required an individual precise characterisation of each sample in case. For this reason finite element simulations of the mechanical deformation behaviour were done separately for each sample and the local strain and stress along the gauge-length was obtained. These differences in samples' geometry point out also that damage evolution should be followed in each sample individually.

During the first 3 shifts we have characterised the initial undeformed state of 10 composite samples and the damage amount in other 6 control samples which were deformed until different percentage of their fatigue life. The latters were used to accordingly design the investigated states in the first 10 samples, which will be followed from the nondeformed state until their rupture. Fatigue damage of PMMC consists mainly of two types: particle breaking and matrix decohesion. For this reason both were evaluated form the microtomographic reconstructions. Local damage appears in black in the tomographic reconstructions and it is possible by selecting a threshold value to binarise the damaged volumes. In principle it is also possible to distinguish automatically between broken and debonded particles, however the algorithm used was not tested enough and we have evaluated manually the two types of damage from two-dimensional cuts parallel to the stress axis. 10-15 different cuts were used, counting of about 250 broken- and 700 debonded particles for each sample. The area density of broken and debonded particles as a function of the cycle number are shown in Fig. 1. and 2. respectively. The last two data points correspond to cracked samples.

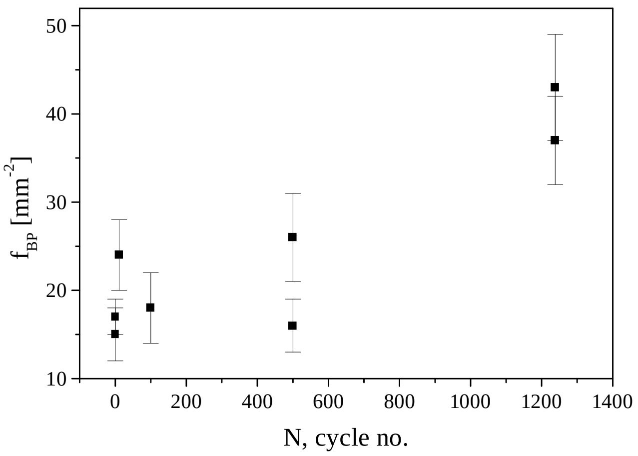

Fig. 1. Area density of broken particles as a function of fatigue cycle number.

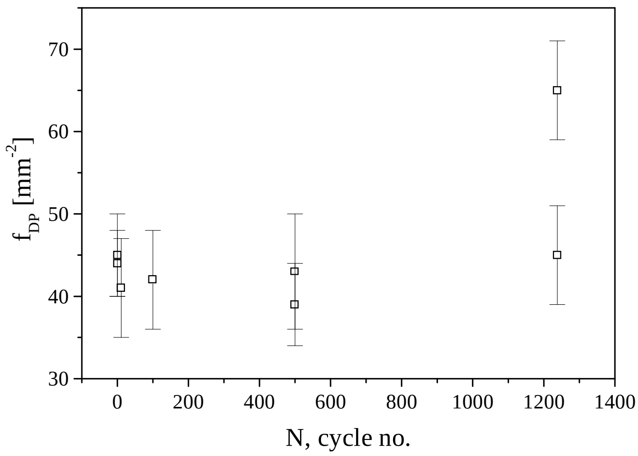

Fig. 2. Area density of debonded particles as a function of fatigue cycle number.

Even if the evaluation error is quite large one can see from Figs. 1 and 2. that different samples can have different amount of damage, which is especially true for particle breaking. These differences between the samples are in accordance with the finite element simulations, in the sense that damage should be followed in each sample separately.

According to Figs. 1 and 2 the relative increase in the number of broken particles is larger as the relative number of decohered volumes, i.e. the particle breaking is the main type of damage during fatigue of PMMC. It is also visible from Fig. 1 that little damage takes place until about the half of the fatigue life, which indicates that, the states to be investigated should be biased towards the end of the fatigue life. We hope that automatic distinguishing between broken and debonded particles will improve the accuracy of the evaluations and other important statistical parameters such as the correlation between the position of broken particles can be evaluated.

During the second round of measurements (19.02.2002-20.02.2002) we have measured the first deformed states of PMMC samples, fatigued with different strain amplitudes of 0.3%, 0.4% and 0.6%. The evaluation of these reconstructions is under way.